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TMDL Model Evaluation and Research Needs

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Abstract

The report was submitted in fulfillment of contract number 68-C-04-007 by Tetra Tech, Inc., under the sponsorship of the United States Environmental Protection Agency. This review examines the modeling research needs to support environmental decision-making for the 303(d) requirements for development of total maximum daily loads (TMDLs) and related programs such as 319 Nonpoint Source Program activities, watershed management, stormwater permits, and National Pollutant Discharge Elimination System (NPDES) discharge evaluations. By examining the currently available models and considering the needs for TMDLs and related watershed programs, a comprehensive list of modeling research needs can be developed.

More than 65 currently available models were evaluated for their capabilities and applicability to TMDL development and related watershed management activities. Evaluation tables were developed to facilitate comparison of models and inventory the potential gaps in model capabilities, and fact sheets were developed for models to provide more detailed information on the capabilities of each model. Existing integrated models systems were also evaluated and compared, based on data processing, modeling tools, and model linkages supported. The review of available models demonstrates that many of the dominant pollutant types and waterbodies can be simulated using available technologies. However, many specific technical gaps remain, especially in linkages between air, surface water, groundwater and receiving water models.

The model reviews and emerging trends in technology were considered in developing a comprehensive list of research needs that encompass a variety of sources, processes, waterbodies, data, systems, and integration needs. This diversity of needs is consistent with the current development of TMDLs across the country. Initially, TMDL development focused on dominant source and pollutant types, but more recently, emphasis has shifted to completing TMDLs under a variety of site-specific conditions and supporting more detailed implementation planning. Because of the specialized and diverse characteristics of the needs, an equitable prioritization of specific needs cannot be defined. Key recommended research areas that could benefit multiple applications include: integrated best management practice (BMP) modeling systems, more physically based representation of watersheds, and support for linkage of watershed and receiving water models.

The review recommends that this diverse set of technical needs should be supported by new and more flexible modeling systems and tools. Development of integrated modeling systems can provide the commonly needed tools and support adoption of new solution techniques, source representation, and algorithms. Providing integrated system platforms, ideally Internet-based, can help minimize duplication of effort (shared on line data management, data display, shared resources), while maximizing resources for more fundamental development and research of key components. The use of Internet-based technologies has now emerged as a viable and practical medium for management of data, analysis techniques and tools to support TMDL and more generalized watershed analyses. Development of a standardized Internet-based framework could provide significant cost saving for the management and application of models. In addition, a standardized and open framework, with clearly defined linkage capabilities, could encourage research and continuous testing and update of new components.

Future development of models and the supporting infrastructure of data and guidance can support informed environmental decision-making, improve understanding of the physical systems in our world, and ultimately provide information to support the effective restoration and protection of the nation's waters.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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GLEAMS: Groundwater Loading Effects of Agricultural Management Systems

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Availability: Nonproprietary
http://sacs.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm
Cost: N/A

Model Overview/Abstract

Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) is an extension of Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model. GLEAMS, a continuous simulation, field-scale model assumes that a field has homogeneous land use, soils, and precipitation. The four major components of the model are hydrology, erosion/sediment yield, pesticide transport, and nutrients. It also estimates surface runoff and sediment losses from the field. GLEAMS can be used to evaluate the impact of farm-level management practices on potential pesticide and nutrient leaching within, through, and below the root zone. GLEAMS can provide estimates of the impact management systems, such as planting dates, cropping systems, irrigation scheduling, and tillage operations, have on the potential for chemical movement. GLEAMS can also be useful in long-term simulations for pesticide screening of soil/management. The model tracks movement of pesticides with percolated water, runoff, and sediment. Upward movement of pesticides and plant uptake are simulated with evaporation and transpiration. Degradation into metabolites is also simulated for compounds that have potentially toxic bi-products. Erosion in overland flow areas is estimated using a modified Universal Soil Loss Equation. Erosion in chemicals and deposition in temporary impoundments such as tile outlet terraces are used to determine sediment yield at the edge of the field.

Model Features

- Edge of field simulation model

Model Areas Supported

Watershed	Low
Receiving Water	None
Ecological	Medium
Air	None
Groundwater	Medium

Model Capabilities

Conceptual Basis

GLEAMS is a physically based field-scale model.

Scientific Detail

The hydrology component of GLEAMS uses a mass balance approach and represents the principal hydrologic processes of infiltration, runoff, water application by irrigation, evapotranspiration, and soil water movement within and through the root zone. Runoff calculation is based on the modified Soil Conservation Service (SCS) curve number method. Percolation is calculated using storage-routing technique. Plant evapotranspiration is calculated using either Priestley-Taylor or Penman-Monteith method. Erosion is calculated as detachment and transport processes using USLE elements. The nutrient component of GLEAMS simulates the nitrogen and phosphorous cycles. The pesticide component of the model calculates the daily decay based on the pesticide half-life. Based on the partition coefficient, a portion of the pesticide is lost into runoff solution and the other part into the soil phase.

Model Framework

- Edge-of-field and bottom-of-root zone simulations of water, nutrients and pesticides
- Mainly used to simulate management systems in agricultural land

Scale

Spatial Scale

- One-dimensional field-scale

Temporal Scale

- Daily

Assumptions

- Uses a lumped parameter approach
- Assumes a spatially homogenous agricultural field

Model Strengths

- Is a simple model with few input requirements

Model Limitations

- Is limited to an agricultural field of very small size
- Is not suited for bigger watersheds
- Is not suited for urban land uses

Application History

GLEAMS is developed as an improvement over CREAMS model. Both models have sufficient application history. http://sacs.cpes.peachnet.edu/sewrl/Gleams/glmspub.htm.

Model Evaluation

Many peer-reviewed publications are available for GLEAMS. Few studies are conducted to evaluate the accuracy of GLEAMS and to compare with similar models like EPIC and WEPP.
http://sacs.cpes.peachnet.edu/sewrl/Gleams/glmspub.htm.

Model Inputs

The inputs are provided separately for hydrology, erosion, pesticides, and nutrient components of the model. The input requirements of the hydrology model include

- Daily precipitation
- Mean monthly minimum and maximum temperatures or mean daily temperature
- Mean monthly solar radiation
- Mean monthly wind movement and dew point temperature, if Penman-Monteith method is chosen for evapotranspiration calculation
- Soil composition

The input requirements of the erosion component include

- Overland flow profile (length and slope)
- Soil properties (erodibility and horizon depths)
- Overland flow channel rating-curve properties

The pesticide component's input requirements include

- Crop rotation information
- Water solubility and partitioning coefficient of pesticide
- Half-life, initial concentration, and fraction available for washoff for foliage and soil
- Crop uptake coefficient

The nutrient component's input requirements include

- Crop rotation information
- Initial soil concentration and concentrations of nutrients in rainfall and irrigation water
- Fertilizer application rate
- Crop uptake coefficient

Users' Guide

Available online:
http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_v2k_update.htm#GLEAMS%20V3.0%20Revisions

Technical Hardware/Software Requirements

Computer hardware:

- IBM-PC

Operating system:

- PC-DOS

Programming language:

- FORTRAN

Runtime estimates:

- Minutes

Linkages Supported

None

Related Systems
CREAMS is the predecessor of GLEAMS.

Sensitivity/Uncertainty/Calibration
Not available

Model Interface Capabilities
- ArcView GIS interface (see Tucker et al. 1996 and http://www3.bae.ncsu.edu/Regional-Bulletins/Modeling-Bulletin/asae_2227-draft-extra.html)

References
Knisel, W.G., and F.M. Davis. 2000. *GLEAMS: Groundwater Loading Effects of Agricultural Management Systems. Version 3.0.* Publication No. SEWRL-WGK/FMD-050199. U.S. Department of Agriculture, Agricultural Research Service, Southeast Watershed Research Laboratory, Tifton, GA. 191 pp.

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Tucker, M. G., D. L. Thomas, and D. D. Bosch. 1996. *GLEAMS and REMM GIS-based model system: results and sensitivity of hydrologic components.* ASAE Technical Paper No. 96-2022. ASAE, St. Joseph, MI.

More publications: http://sacs.cpes.peachnet.edu/sewrl/Gleams/glmspub.htm